Characterization of discharge based plasmas in the spectral range of 20-50 nm

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CONTENT

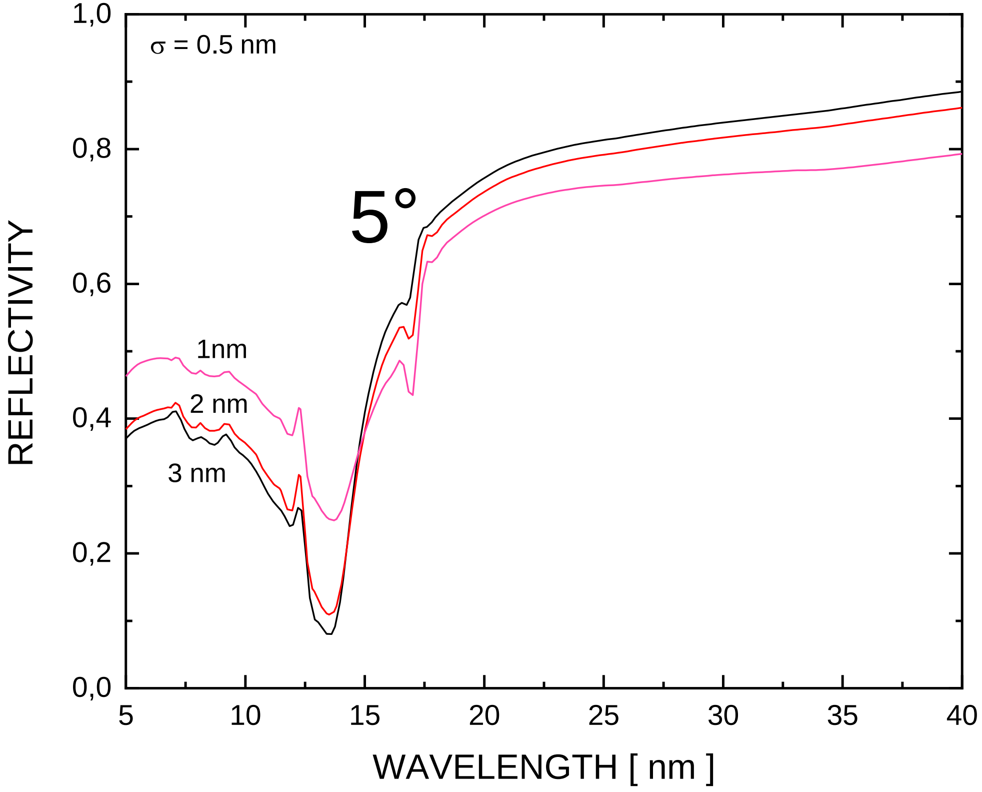
- Motivation for 20 nm – 50 nm
- Experimental set-up
- Results on emission for different gases
- Conclusions

Why dealing with 20-50 nm ?

- higher relative Mie scattering compared to 193 nm, benefit for defect inspection using 47 nm[1]
- increase of reflectivity with wavelength coming from lower wavelengths
- higher reflectance angle, better spatial resolution larger data set for reconstruction of parameters

  - characterization of layer systems
  - spectroscopic reflectometry for periodic structure characterization[2]

Determination of Al_2O_3 thickness on silicon substrate



Ref.: CXRO – The Center for X-Ray Optics (http://www.cxro.lbl.gov/)

[1] Ref.: Barnes et al., SPIE Advanced Lithography 2017, Metrology, Inspection and Process control for Microlithography XXXI, Vol. 10145, 2017

[2] Ref.: Bahrenberg et al., SPIE Advanced Lithography 2019, Metrology, Inspection and Process control for Microlithography XXXIII, Vol. 10959, 2019

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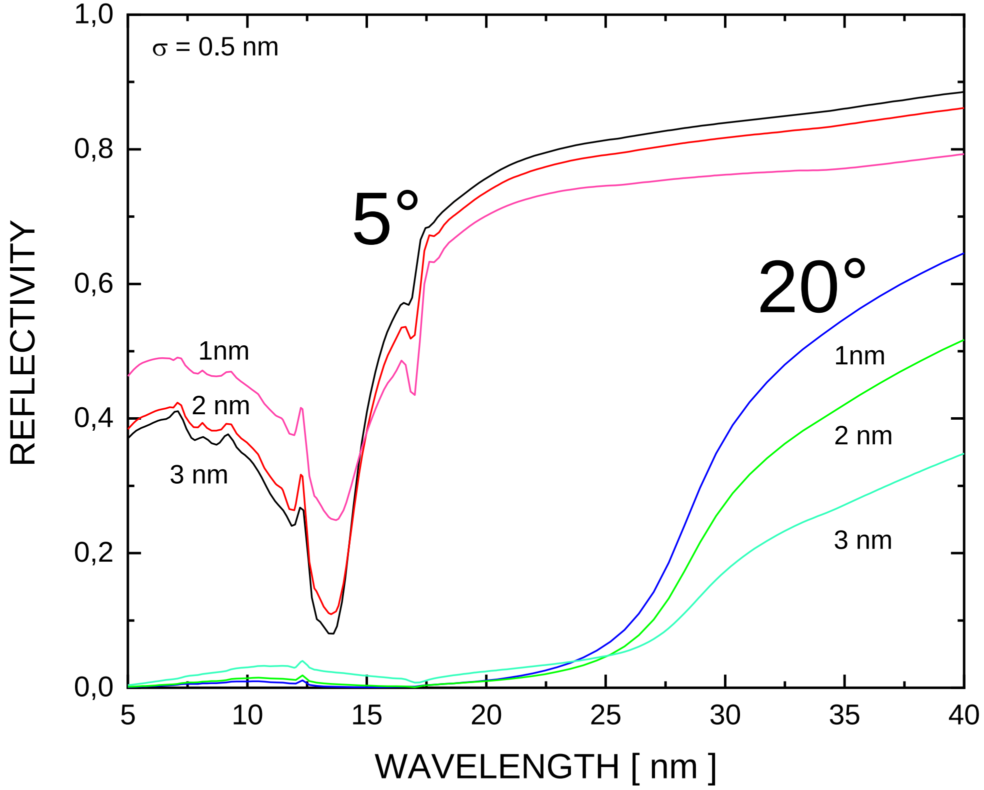

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Opportunities and challenges with discharge plasmas

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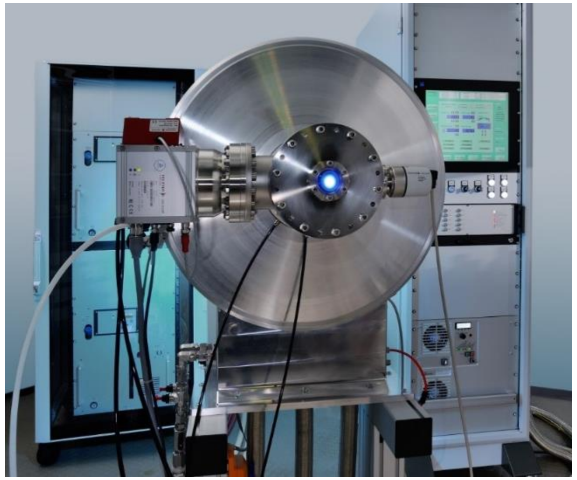
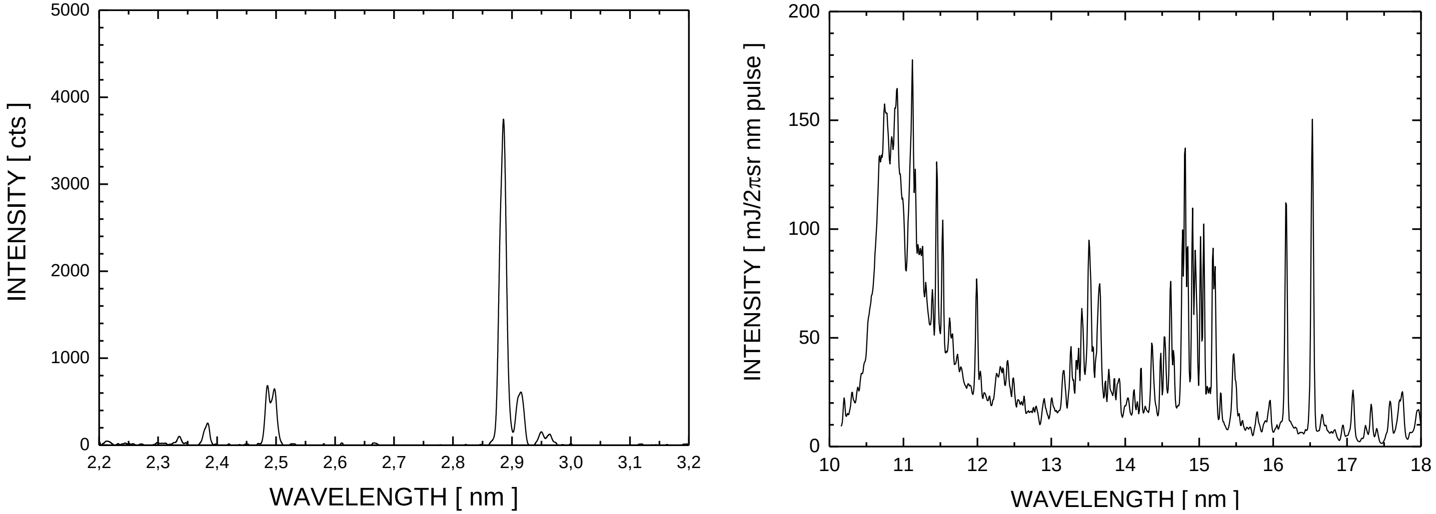
XUV source



- Starting point for development:
  - pinch plasma source optimized for 2-20 nm
  - electrical input energy ~ 2-10 J
  - average input power up to 10 kW
- Optimized emission for 20-50 nm is expected at lower plasma temperature/lower input energy
  - lower electrode erosion
  - longer maintenance interval
  - lower Cost of Ownership
- Planck radiator: lower temperature means broader wavelength interval
- Technical challenge to produce colder plasma with high density

Emission spectra of nitrogen and xenon



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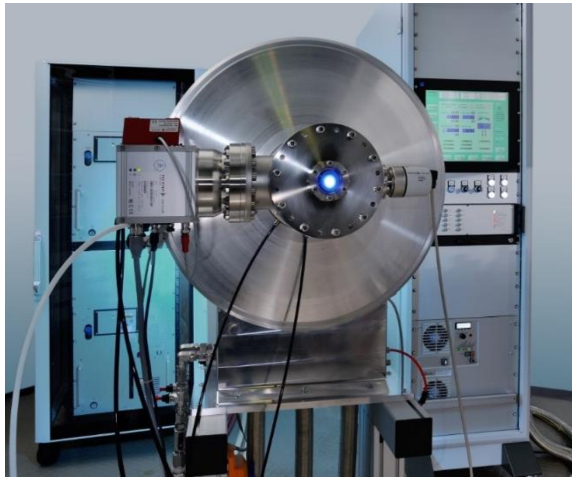
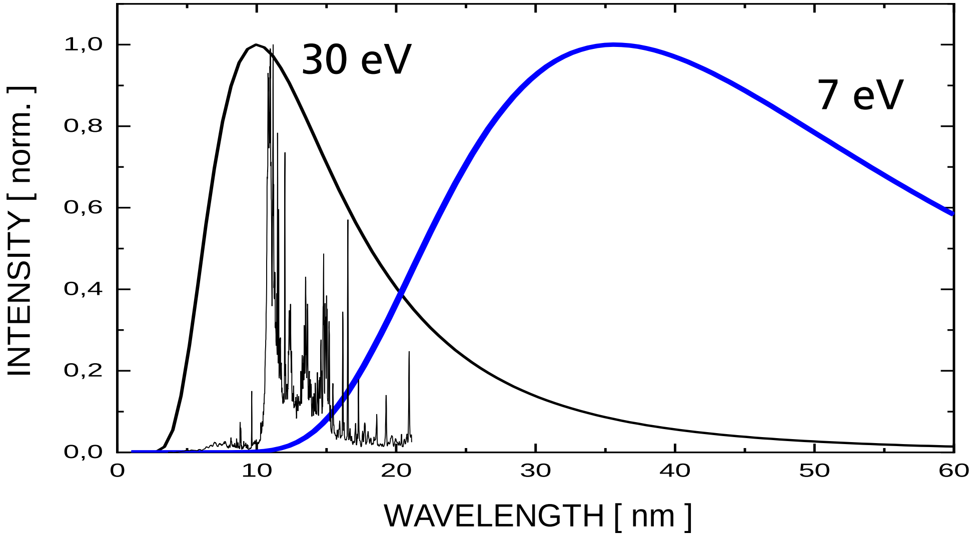
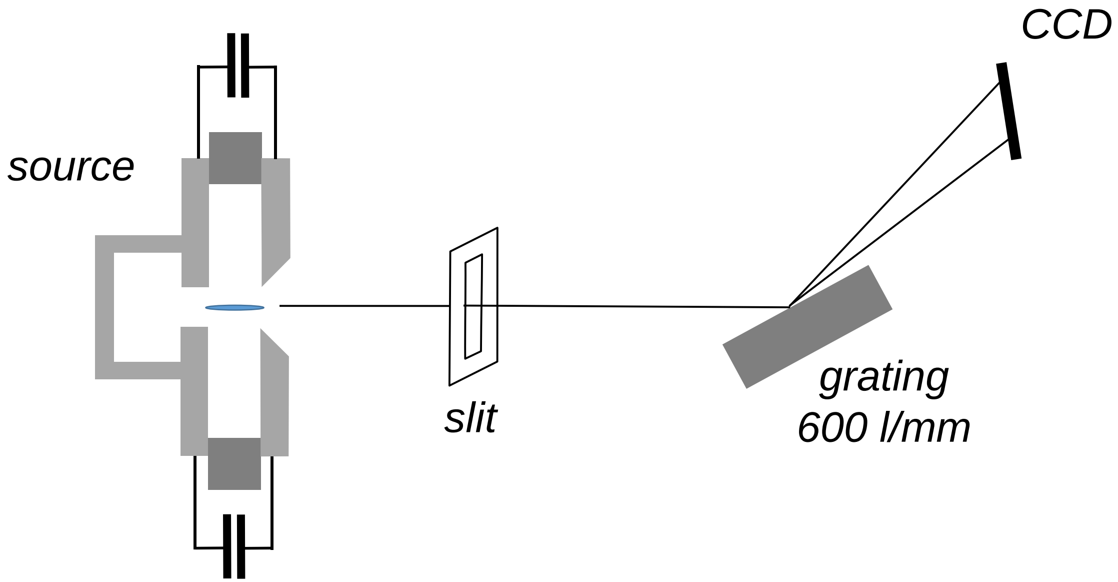
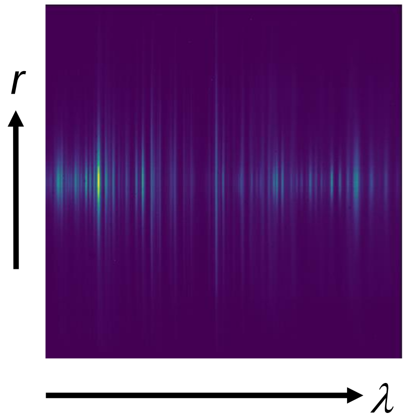




Experimental setup for 20 - 50 nm characterisation

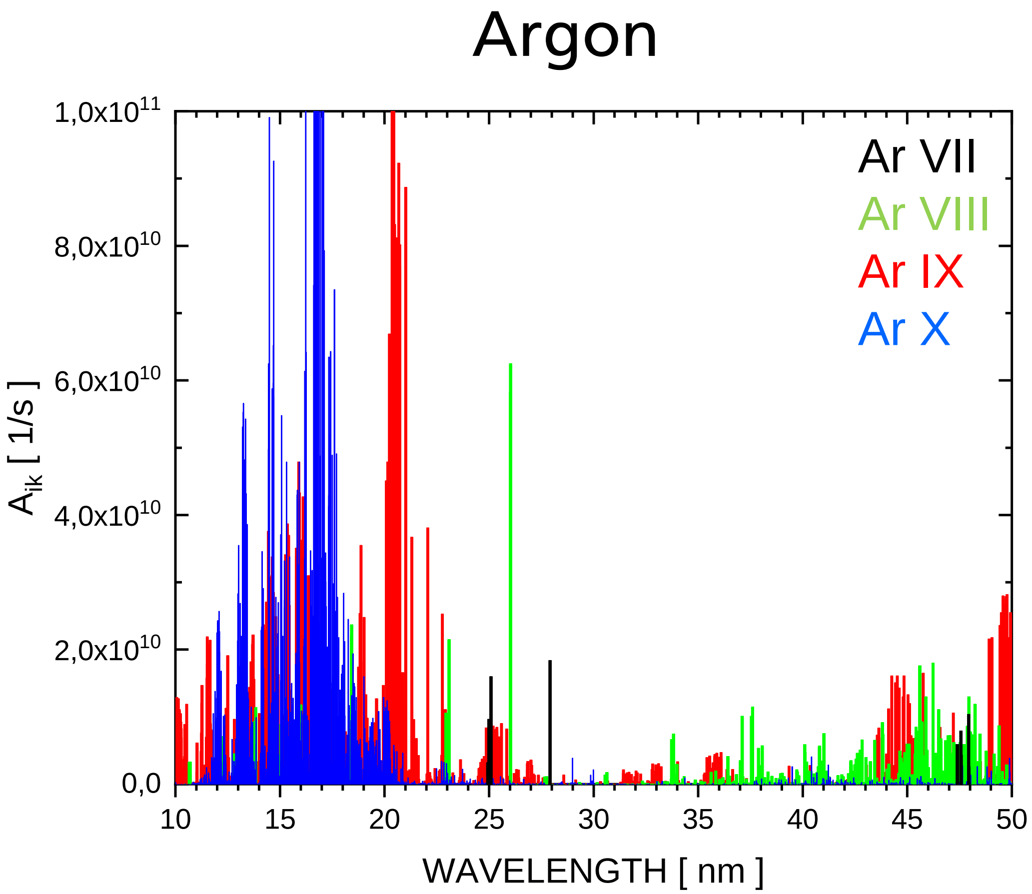
- Hollow Cathode Triggered pinch plasma:
  - repetition rate 20 Hz - 30 Hz
  - input energy 1,3 J - 2,3 J
  - operation with Ne, Ar, Kr, Xe
- emission spectra recorded with grazing incidence spectrograph (600 lines/mm)
- spectrally resolved end-on emission profile using slit perpendicular to entrance slit of spectrograph (Abel inversion)
- absolute emission estimated with photo diodes + spectral filters

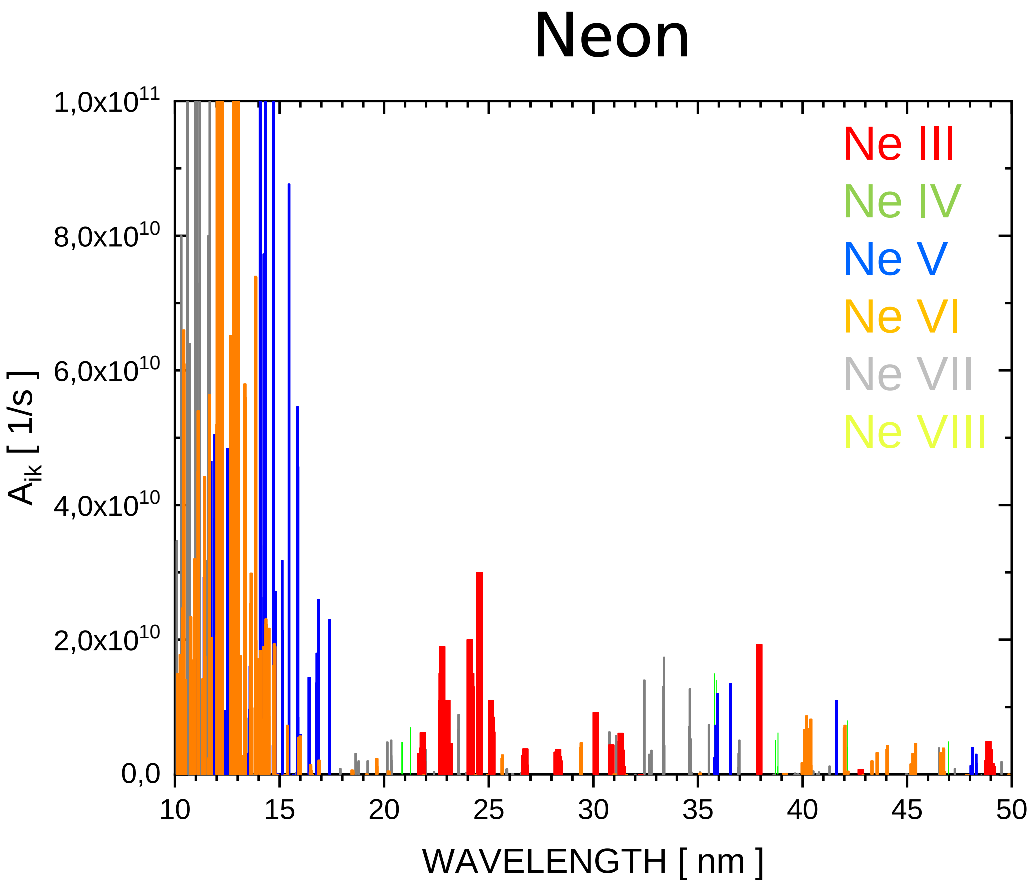




Raw data spectrograph

Atomic data

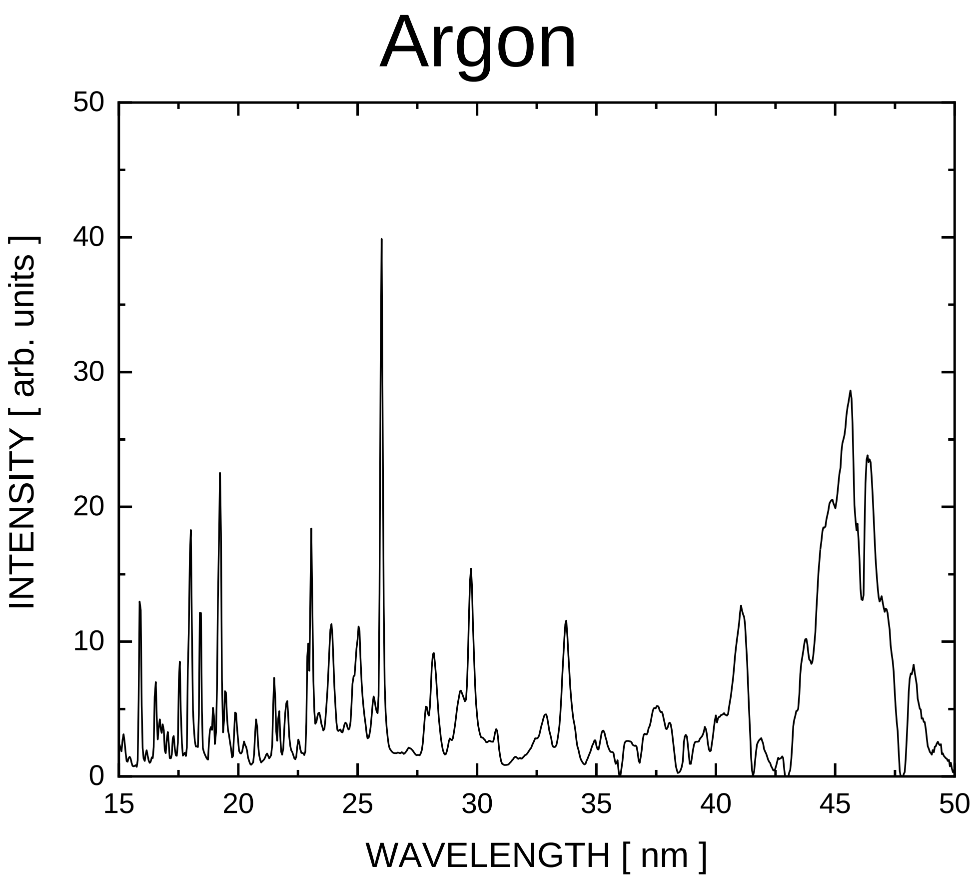


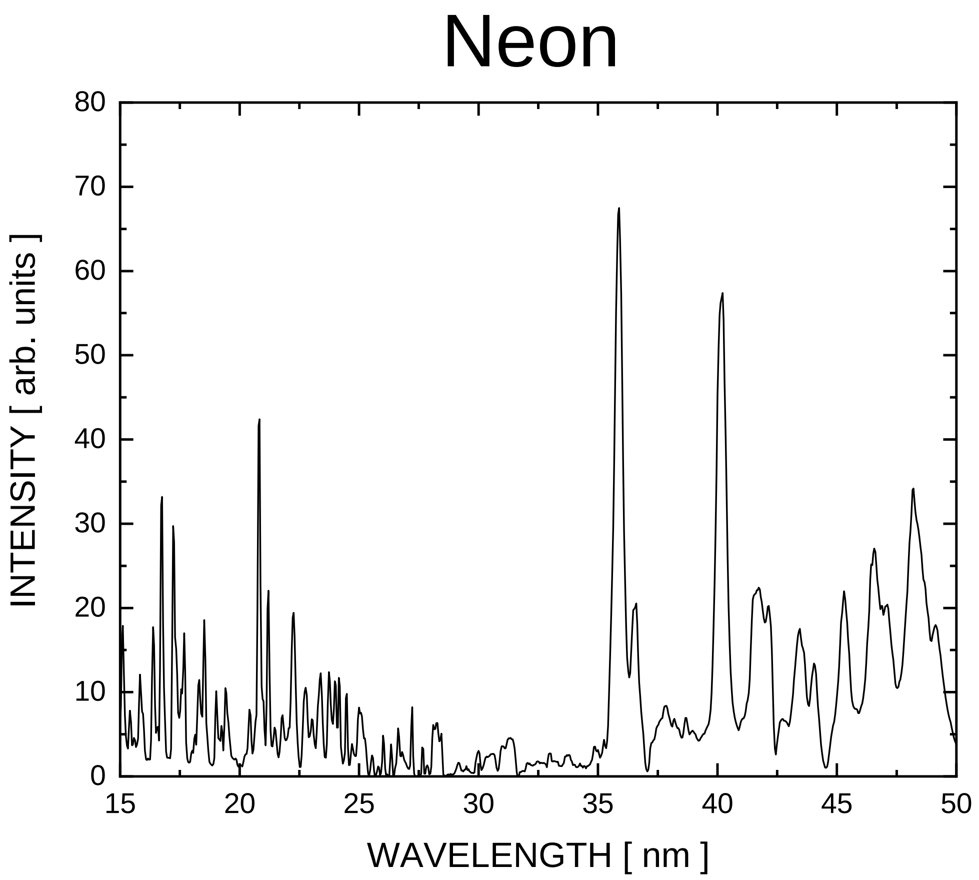


Ref.: CHIANTI - An Atomic Database for Spectroscopic Diagnostics of Astrophysical Plasmas (https://chiantidatabase.org/sswidl/dbase/ar/)

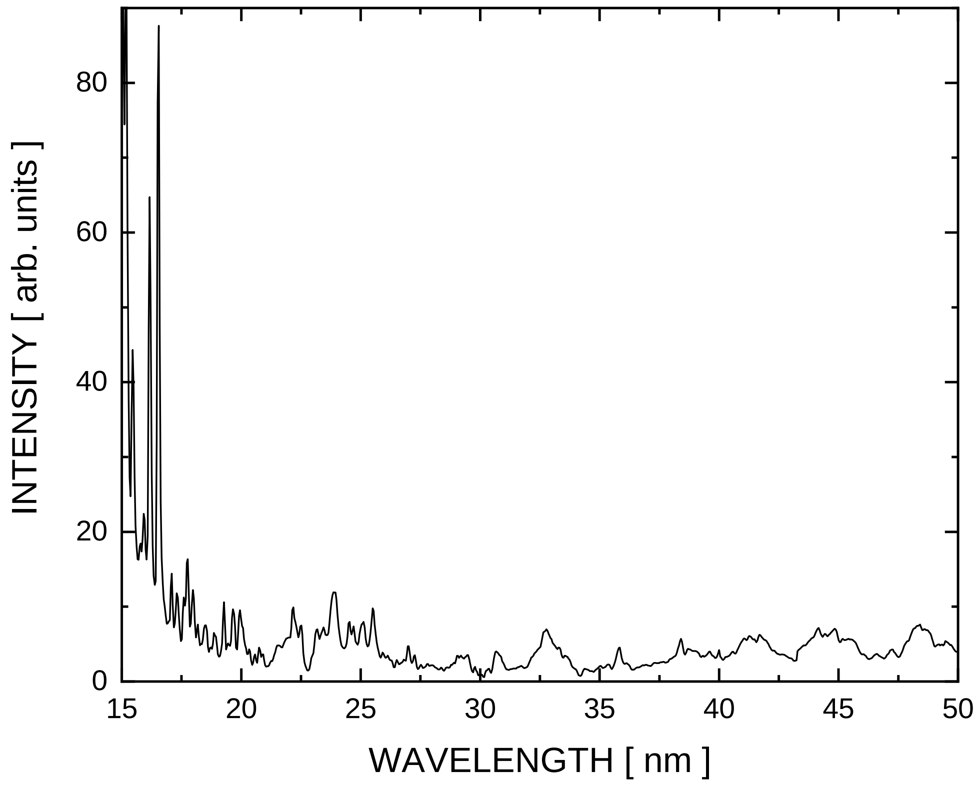
Ref.: National Institute of Standards NIST – Atomic Spectra Database (https://nist.gov/pml/atomic-spectra-database)

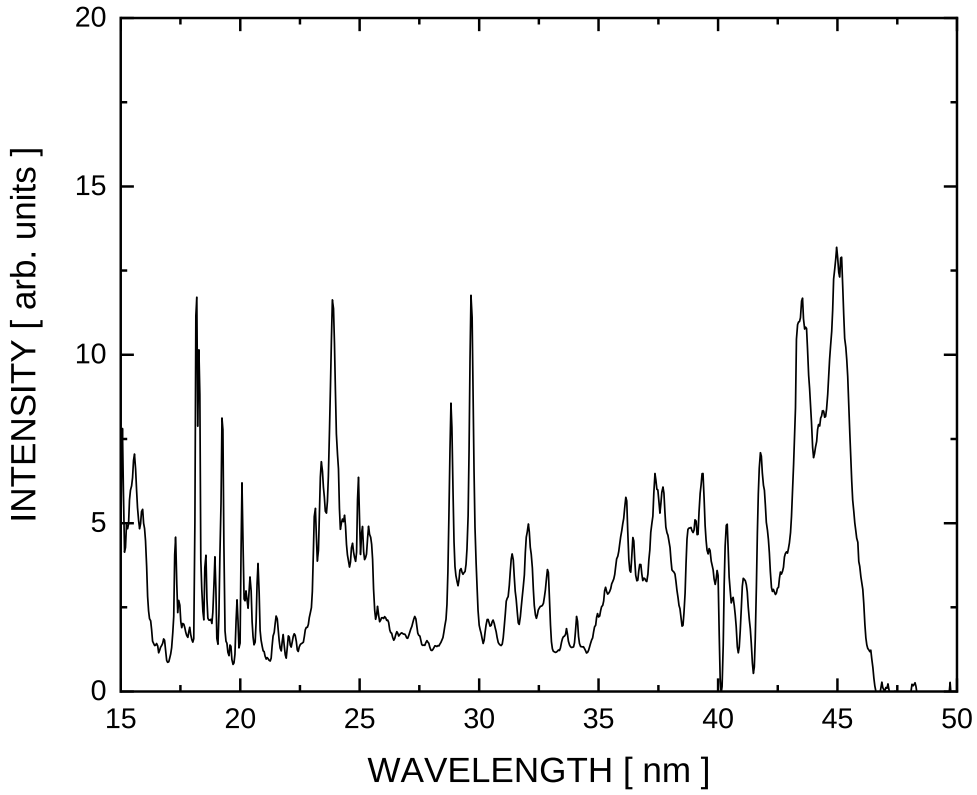
Emission spectra (1)



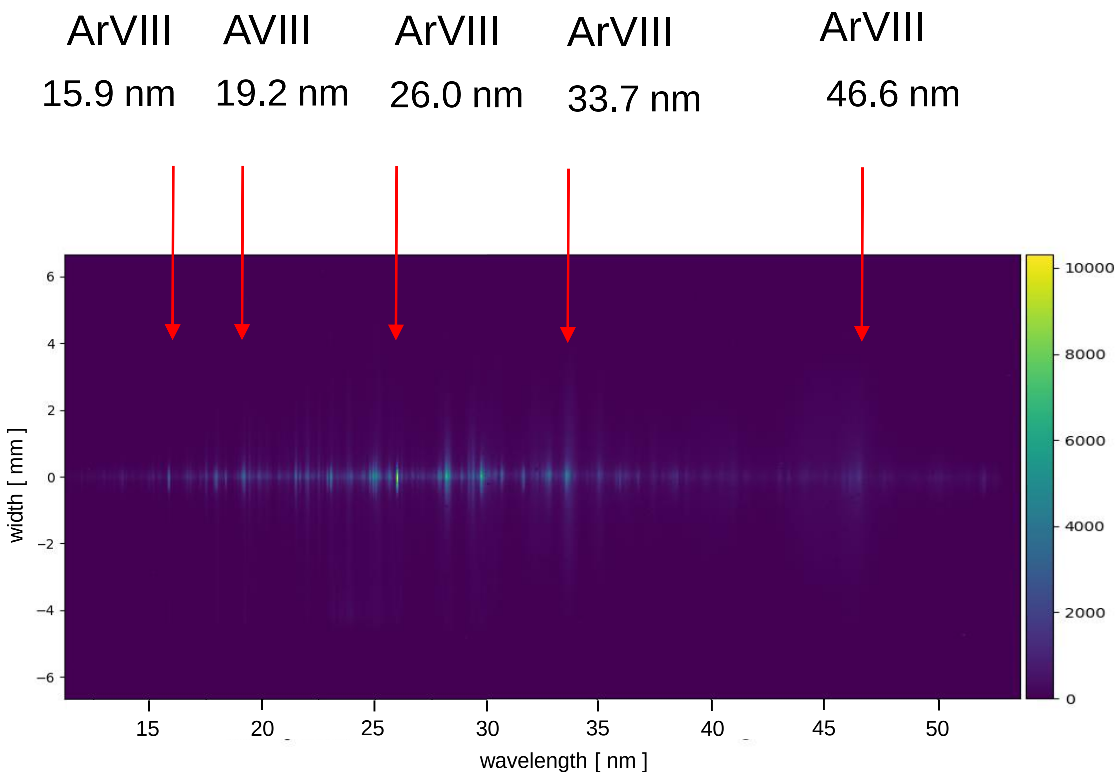


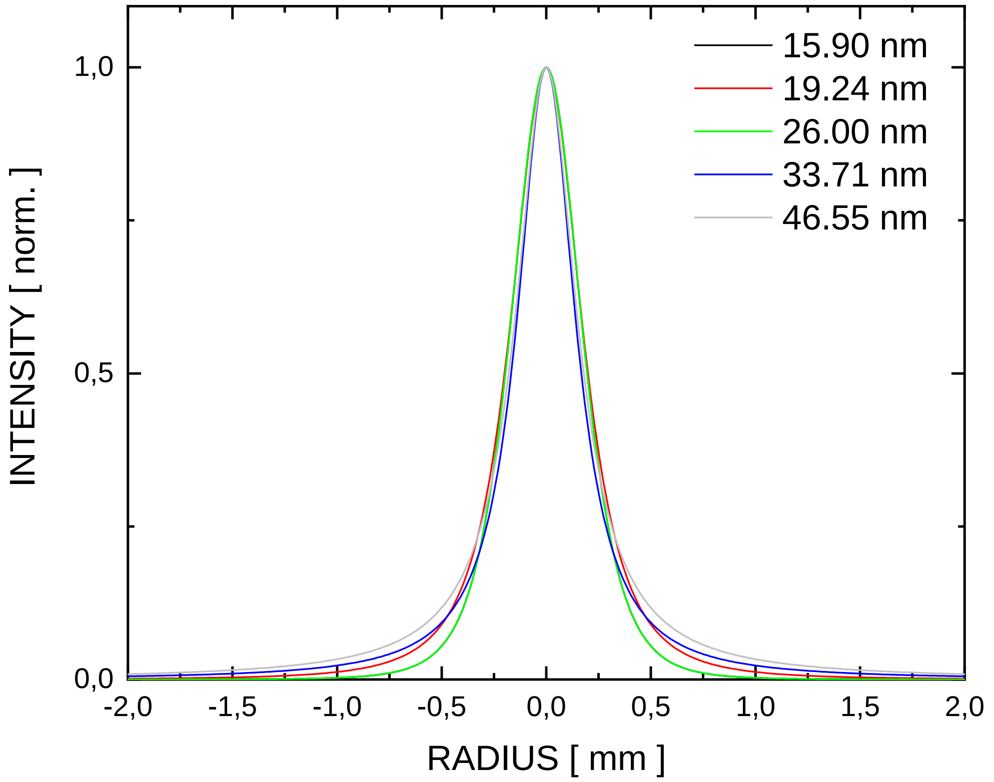
Emission spectra (2)


Xenon

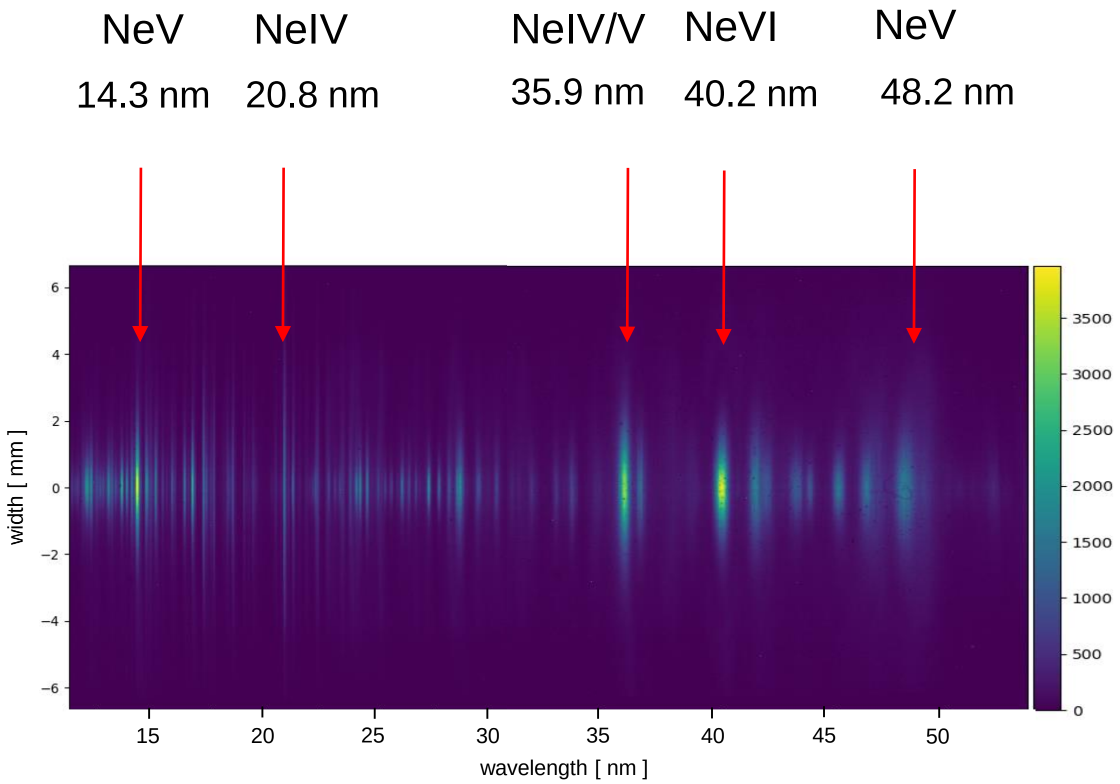

Krypton

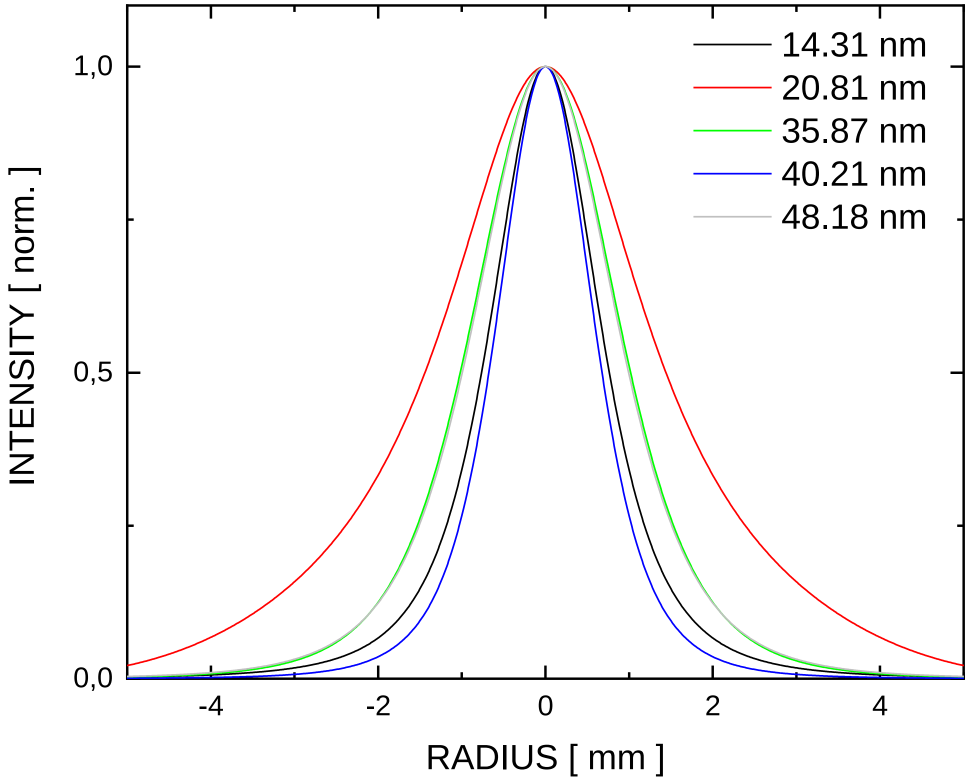
Spatial profiles: Argon





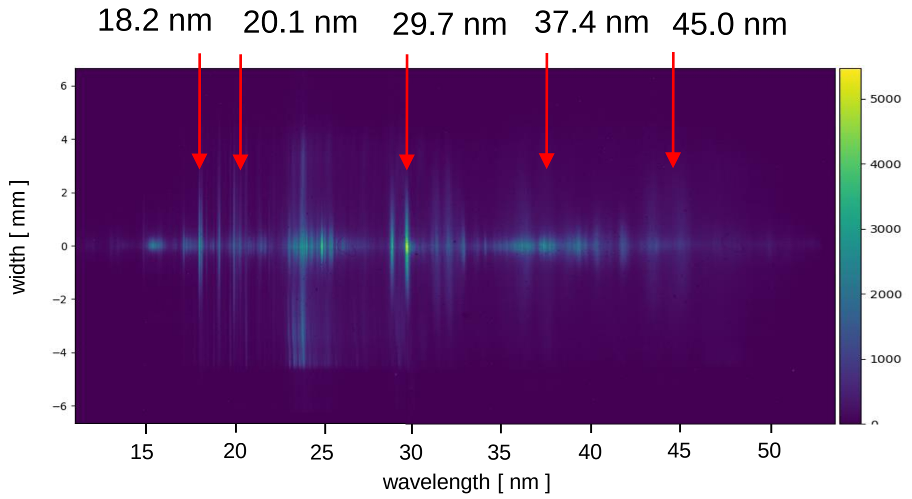
Spatial profiles: Neon

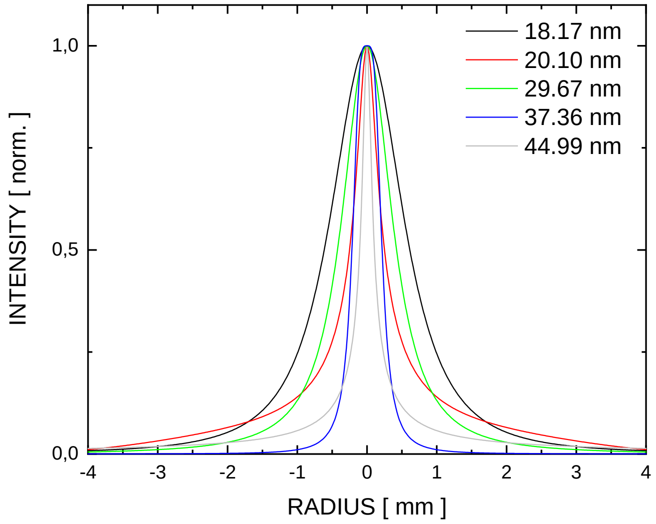




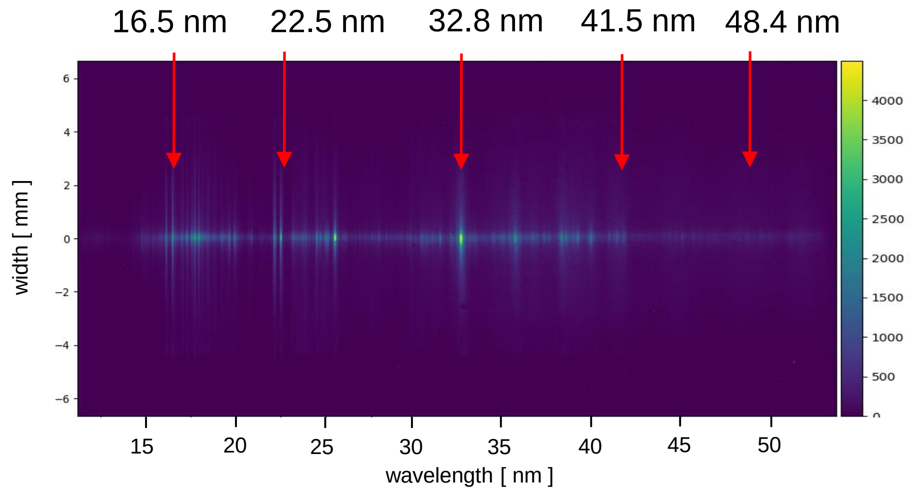
Spatial profiles: Krypton, Xenon

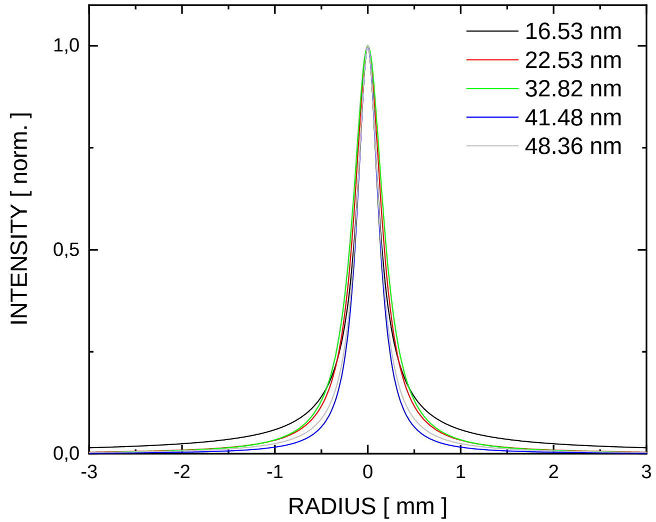
Krypton



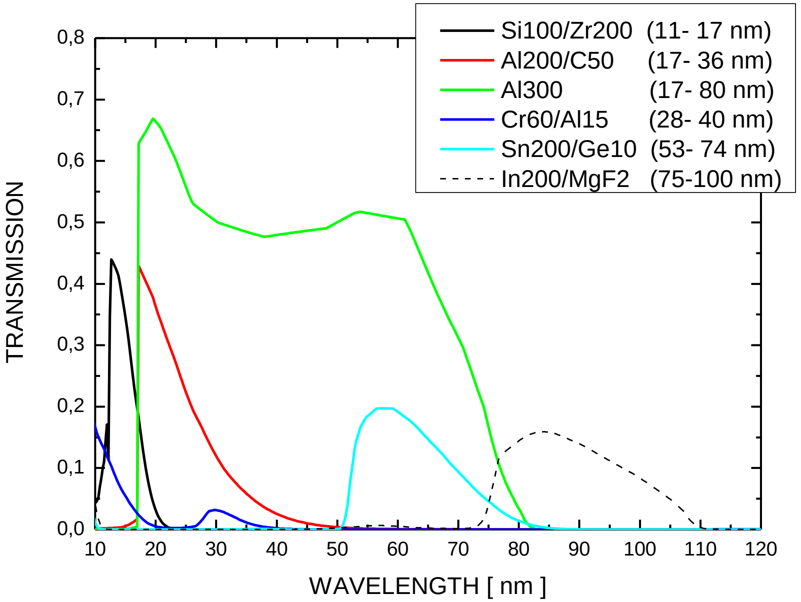


Xenon

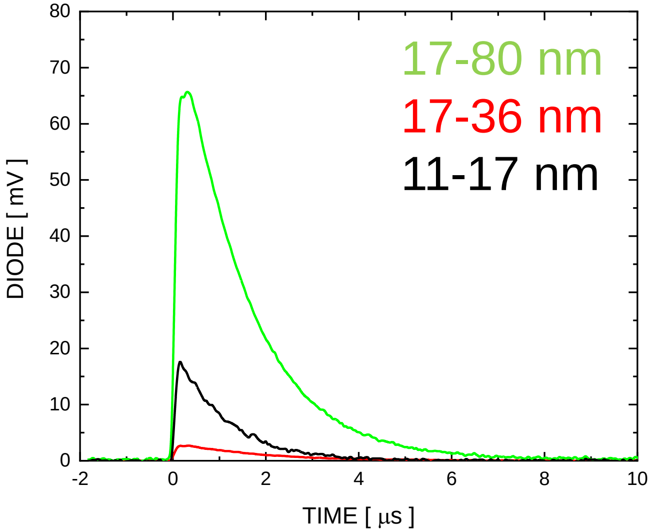




Estimation of absolute emission

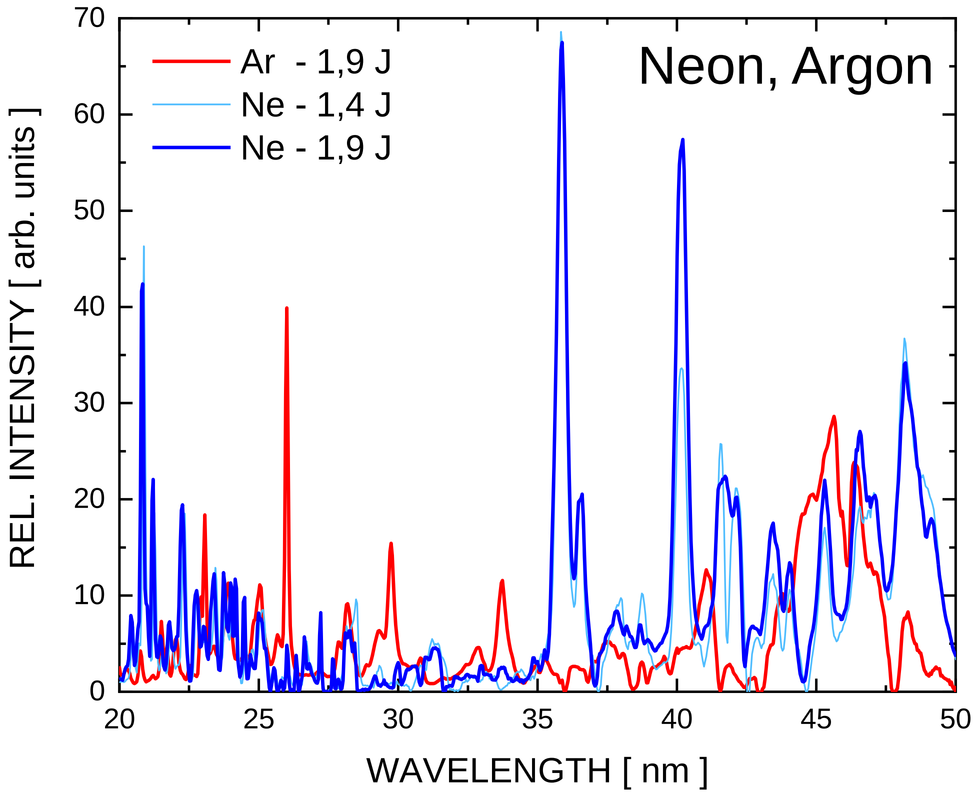


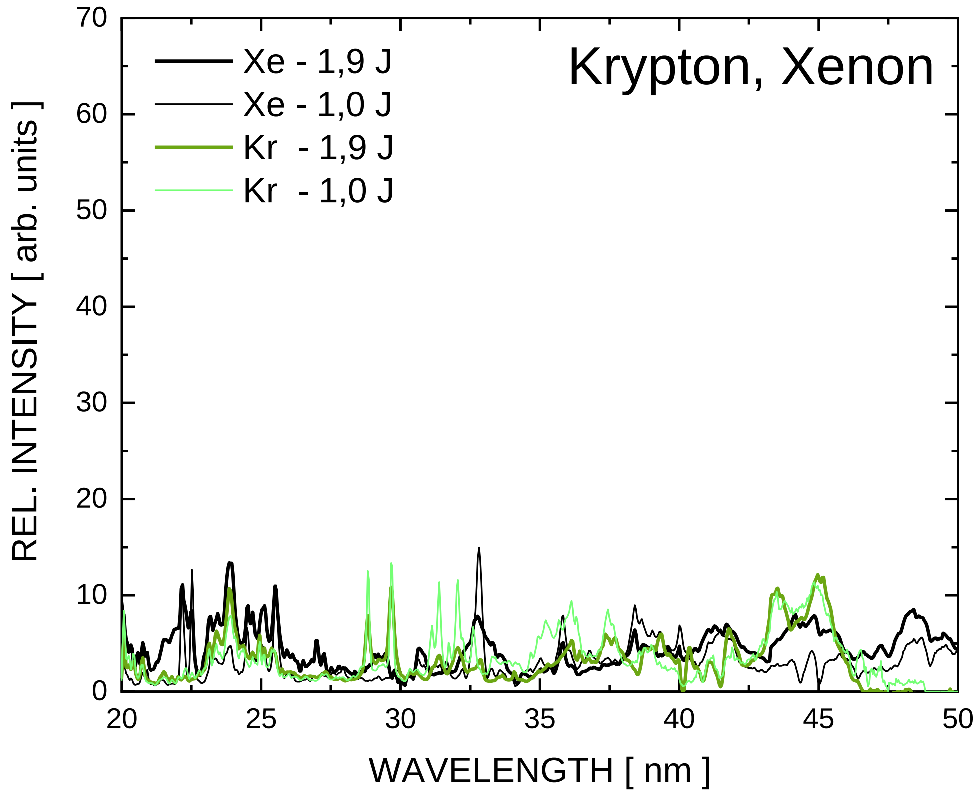
- nine AXUV 100 diodes
- sensitivity from suppliers data sheet (~ 0,2 A/W)
- different coatings for discrimination of spectral ranges
- correction for self-absorption in beamline



typical diode signals

Overview emission spectra





- emission spectra normalized to input energy (same scale for all elements !)
- expected total energy for Neon in wavelength interval 20-50 nm : $E_{20-50} \sim 100$ mJ/2πsr
  (rough estimation !!) CE ~ 4 %/2πsr

Summary and conclusion

- Investigation on 20 nm - 50 nm emission of different gases in a ~2 J discharge plasma (Neon, Argon, Krypton, Xenon)
- Observed transitions of NeIV - NeVI and ArVIII
- "Large" range of diameter for different gases and for different ionization levels (up to 4 mm for NeIV)
- Highest conversion efficiency for Neon ~100 mJ/2πsr (~4 %/2πsr)

see also poster S68:
Vieker et al., The Effect of Gas Admixture on the Operation of a Discharge based EUV-Source

THANK YOU !!